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SHORT COMMUNICATION

Accuracy improvement of geometric correction for CHRIS data

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Abstract: This paper deals with a new type of multi-angle remotely sensed data---CHRIS (the Compact High Resolution Imaging Spectrometer), by using rational function models (RFM) and rigorous sensor models (RSM). For ortho-rectifying an image set, a rigorous sensor model-Toutin's model was employed and a set of reported parameters including across track angle, along track angle, IFOV, altitude, period, eccentricity and orbit inclination were input, then, the orbit calculation was started and the track information was given to the raw data. The images were ortho-rectified with geocoded ASTER images and digital elevation (DEM) data. Results showed that with 16 ground control points (GCPs), the correction accuracy decreased with view zenith angle, and the RMSE value increased to be over one pixel at 36 degree off-nadir. When the GCPs were approximately chosen as in Toutin's model, a RFM with three coefficients produced the same accuracy trend versus view zenith angle while the RMSEs for all angles were improved and within about one pixel.

Keywords: CHRIS; ortho-rectify; rigorous sensor model; rational function model

Introduction

Raw images usually contain significant geometric distortions that cannot be used directly with existing geocoded map-like products for spatial analyses, which is more essential for quantitative remote sensing researches. Multi-angle remote sensing is generally believed to provide a potential to record the directional anisotropy of reflectance from vegetation canopies (Barnsley et al. 2000). Geometric correction process becomes more important for off-nadir viewing images with finer resolution. Images of a set of viewing angles of the same target and from the same sensor are distortable to various magnitudes. These data need to be recovered by geometric and radiometric processing before integrating for applications in geomatics. These processing should adapt to the nature and characteristics of the data for keeping the best information from each image in the composite ortho-rectified products. Researchers around the world have developed models and mathematical functions to perform geometric corrections of images, including polynomial model, rational function models (RFM) and rigorous sensor models (RSM) (Zhang & Chen 2005). The latter concerns every detail in the imaging process that might generate distortions, which requires complete information of viewing geometry, and can produce the most precise correction. However, accurate track information is not generally available to terminal users. The former two are empirical models, for which all the information for correction can be acquired from GCPs and are independent of imaging parameters (Liu et al. 2002). Their shortcoming is obvious and difficult for generalization. They can be taken as alternative to RSM model. If the track information is available, RSM is the first choice among the three models. Few articles mention to comparison of multi-angle images with track information between RFM and RSM. In this paper, we first used a RSM model–Toutin's model for correction, and then RFM method for the same images with track and viewing information. The results were compared in detail and the latter Root-Mean-Squared (RMS) statistics was better.

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Materials and methods

CHRIS data

CHRIS/Proba is a high spatial resolution, hyperspectral and multi-angle satellite sensor on trial, launched by ESA in 2001, which can provide a set of images for the same object from five viewing angles. CHRIS bands are set within visible and infra-red

(VIR) spectrum. Different modes vary in band number or center wavelength. The Chlorophyll Mode (Mode 4) is used in this paper, there are 18 bands ranging from 486 nm to 788 nm, and spatial resolution is designed to be 17 m at nadir.

There are many researchers working on this new sensor (Chopping et al. 2003; Guanter et al. 2005). However, it is still in trial, and solutions to some basic aspects such as geometric correction and radiometric calibration need further improvement (Alonso & Moreno 2004; Cutter 2004). The geographic center of the image set is (42.17°N, 128.28°E), located in the north slope of Changbai Mountain in Northeast China.

Digital Elevation Model

We used the DEM data at a scale of 1:50 000. The pixel size was sampled to 18 m according to the CHRIS pixel size. The elevation ranges from 914 to 1 349 m (a.s.l.).

Toutin' model

A physical model should mathematically consider all the parameters of the platform (position, velocity, and attitude for VIR sensors), the sensor (viewing angles and panoramic effect), the Earth (ellipsoid and relief for 3D), and the cartographic projection (Toutin 2004). For ortho-rectifying an image set, this paper first employed a rigorous sensor model-Toutin's model, input a set of reported parameters including across track angle, along track angle, IFOV, altitude, period, eccentricity, orbit inclination, and then started orbit calculation and gave the track information to the raw data. Regarding the nominal ground sampling distance, we set 18 m as the output pixel size for all viewing angles. In addition to the above information we carefully selected 16 well distributed GCPs for each viewing angle (Fig. 1). These GCPs were well distributed and carefully chosen, and a marginal number of GCPs were tested to contribute little to improve the statistics. Image at nadir is firstly ortho-corrected according to a geo-coded ASTER image at 15 m resolution with DEM and then used as reference image to correct off-nadir angles.

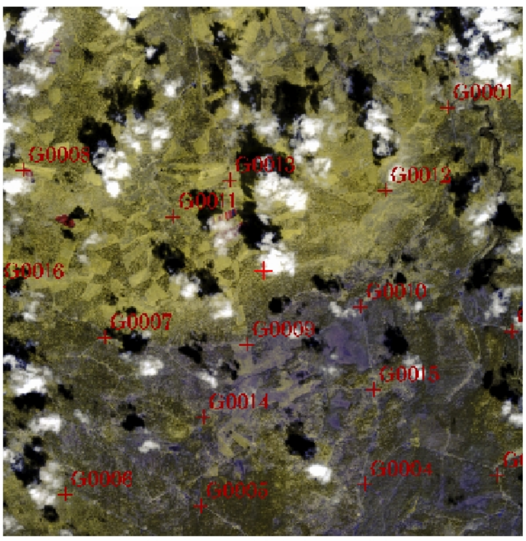

Fig. 1 Raw data and GCPs

Rational function model

The rational functions math model uses a ratio of two polynomial functions to compute the image row, and a similar ratio to compute the image column. All four polynomials are functions of three ground coordinates: latitude, longitude, and elevation. The polynomials are described by using a set of up to 20 coefficients. However, some of the coefficients are often zero. Given the number of coefficient X, it requires ($2X$-1) GCPs. After comparison of precision from the up to eight coefficients that sixteen GCPs can generate, three coefficients can provide a precision of about 1.0 pixel.

Results and discussion

The result of the Toutin's model ortho-correction at 36°viewing angle was shown in Fig. 2. The case of rational function model was not shown since the difference between the two methods was at a level of one pixel. Though the correction result of RSM and RFM hardly showed any difference visually, their statistics of X, Y, and total RMS errors were employed to demonstrate the differences (Fig. 3).

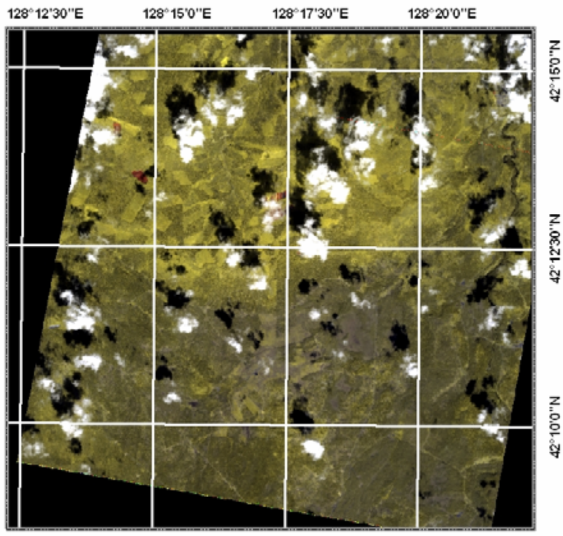

Fig. 2 Ortho-rectified image

Both RFM and RSM show an increasing trend of RMS errors with viewing angles (Fig. 3). Such a generality existed in X, Y and total RMS errors. The RMS errors of RSM ranged from 0.89 at nadir to 1.31 at 55 degree off-nadir, while the RFM result ranged from 0.80 at nadir to 1.07 at 55 degree off-nadir. Even RMS error of RFM at 55 degree was less than that of RSM at ±36 degree. This suggests that RFM statistics of RPC is better than that of RSM. This result can be understood as less dependency on GCP identification and collection, a widely time-consuming operation and not always a simple task, which requires not only clear sky but also enough ground features contrast to the vegetation background. However, this phenomenon is

unexpected as RSM is believed to have a higher precision. Toutin (2004) described the error sources into two categories, the observer and the observed. As the acquisition process is within 2 min for each five angles, the observed factors should be of the same. Therefore the most obvious difference is the attitude, which belongs to the observer category.

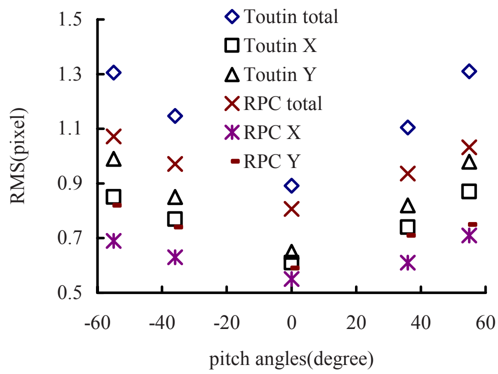

Fig. 3 Comparison of ortho-rectifying precision between RFM and RSM

For CHRIS acquisition, the five angles are assumed to take place within a 55° cone, which assumes a circular orbit with the distance to spacecraft equal to the semi-major axis of the orbit, i.e. constant distance. Actual viewing angles are within this range. In Toutin’s model, the actual viewing angles are required to be calculated. We input accurate acquisition time, with other information we collected, transform the five pair of angles into across track angle and along track angle, and prepared images for Toutin’s model ortho correction.

There is a possibility that both the orbit altitude and movement variation contributed to the errors. Since orbits are higher or lower than the semi-major axis, the cone traced by the satellite during acquisition will be slightly different. For example, in March 2005, the platform altitude varied between 552 and 685 km (CHRIS manual 2004). Also each viewing angle with its movement might cause slight attitude variation. As the viewing geometry changes between each action, distortion problem varies within a set of viewing angles as the case of CHRIS/Proba images. These variations damper the accuracy of platform parameters employed and then the errors in nadir correction propagate to other angles.

Conclusions

Both denominator and numerator of rational function are composed of polynomial expressions. Mathematically, polynomial function can fit perfectly (no error) for those GCPs used to obtain this polynomial function, but there will be big errors for other points. One need randomly pick some points on images and assess the accuracy. We used transparency to visually check the correction effect. Polynomial fitting can reach higher accuracy for these GCPs when its degree rises. To limit the potential underestimation of RMS errors, we used the lowest number of three-coefficient modeling and assumed the number of GCPs (16) was large enough to compare with required numbers. Three-coefficient RFM needs (2*3-1=5 points at least) to build a robust RFM. Obviously, further research is needed to adequately illustrate the phenomenon and answer the relevant questions, such as whether input of images with track parameters contributed to RFM accuracy in this case. Before making clear conclusion, we should first compare the validity of different methods to give an optimal solution.

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